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7N-61-ER  
179601  
P. 26

Final Report  
for Contract 956780  
entitled

**SCIENTIFIC DATA PROCESSING TASK  
(GALILEO)**

submitted  
August 21, 1990  
to

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(NASA-CR-193605) SCIENTIFIC DATA  
PROCESSING TASK (GALILEO) Final  
Report (Arizona State Univ.) 26 p

N94-70279

Unclass

Z9/61 0179601

This final report includes documentation of activities in the pre-launch phase of the Principal Investigator's activities for the Galileo mission, as part of the Solid State Imaging Team.

The goal in this phase was to establish a network of Home Institute Imaging Processing Systems (HIIPS) for the imaging team, including assessment of currently available hardware systems, individual team member responsibilities and requirements in the context of the imaging experiment, and coordination with the JPL Image Processing Facility (MIPL). In addition, a design and implementation plan was developed, as shown in Appendix 1. Following this document, the initial HIIPS system was established. Because of the delay in the launch of Galileo due to the Challenger accident, the original plan was modified to take into account the longer schedule for the mission. Currently, the HIIPS system consists of a collection of hardware systems including those purchased entirely by Galileo, those partly funded by the Project, and those essentially "borrowed" for use by Galileo until the full HIIPS system can be established in FY 1992. Using the current collection of systems, we have coordinated the development of scientific software, the use of the existing system to test network capabilities, and to prepare for data analysis for the cruise phase of the mission.

## **Appendix 1**

# **GALILEO SOLID STATE IMAGING TEAM SCIENTIFIC DATA PROCESSING SYSTEM SOFTWARE/HARDWARE DESIGN and IMPLEMENTATION PLAN**

Submitted August 21, 1990

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## 1 INTRODUCTION

### 1.1 Approach

The eight-year flight of the Galileo (GLL) spacecraft includes 6 years of cruise and pre-encounter operations and 24 months of orbital operations with repeated encounters of Jupiter and several of its satellites. This represents an unparalleled scientific opportunity, as reflected in an extensive list of detailed scientific goals (GLL Science Requirements Document 625-50). The task of processing a minimum of 60,000 frames, coupled with the need for rapid, adaptive data acquisition strategies represents a formidable challenge.

In order to meet this challenge at a minimum cost the GLL Imaging Team has devised the Scientific Data Processing System (SDPS), including use of the Jet Propulsion Laboratory (JPL) Multi-mission Image Processing Laboratory (MIPL) Science Processor and a network of Home Institution Image Processing Systems (HIIPS). The implementation of the HIIPS is outlined in this document. The implementation of the MIPL Science Processor is described in the documentation of the MIPL Implementation Project at JPL. The system minimizes the major costs of previous mission approaches (reliance on high-quality photographic hard copy, hand-tailored color and time-lapse sequence photography, and large travel and subsistence budgets) and maximizes the use of digital records at team members' home institutions. Such an approach is now possible because of the commercial availability of high powered, low-cost computer hardware.

Additional significant benefits that accrue from this plan include:

- 1) The geographic distribution of HIIPS elements that provide image processing and analysis for several team-associated, GLL Interdisciplinary Scientists (IDS's) at their home institutions.
- 2) The increased ability of GLL Imaging Team investigators and IDS's to process, compare, and combine data from

other experiments and from other sources such as the Space Telescope through the use of the NASA computer network.

- 3) The widespread and rapid availability of GLL imaging data and applications software throughout the scientific community for independent scientific investigations after GLL operations.

## 1.2 Scope

This document is a description of the GLL Imaging Team plan for the design, implementation, operation, upgrade and maintenance of a geographically-distributed image processing system for the scientific analysis of GLL data. This document reflects but does not specify any requirements for the implementation or operation of the MIPL.. Details of the use of the MIPL Science Processor during Galileo planetary operations will also be outlined in this document and in corresponding MIPL documentation.

## 1.3 Overview

The objective of this task is to implement an image processing system that meets the requirements of the GLL Solid State Imager (SSI) science team (as set forth in MOS-GLL-4-232) for the scientific analysis of GLL data during mission operations. Key features of this system are:

- 1) A geographically distributed system (HIIPS) covered by this plan, with elements located at team members' home institutions. The purpose of each HIIPS element is to enable team members, team-associated IDS's, and associates (graduate students, etc.) to develop science software for data analysis and to analyze GLL imaging data in digital form at their home institutions.
- 2) A multi-user science processor provided by (MIPL). The purpose of the MIPL science processor is to provide an interactive and user-friendly, digital, multi-user image processing system which will be available to team members and team-associated IDS's when present at JPL

for analysis of GLL data. Team members will spend approximately 30 percent of their time at JPL during mission operations.

- 3) A high speed computer network for information exchange between those systems. Networking of data processing parameters and information regarding mission operations and exchange of scientific results between individual HIIPS elements and MIPL will be possible.

The relationship of the HIIPS system, the MIPL, and other science teams of the GLL Project during cruise and planetary operations is shown in Figure 1-1.

## 2 TASK DEFINITION

The task encompasses the development, procurement, installation, periodic upgrade, management, and use during GLL cruise and mission operations of geographically-distributed image processing facilities located at team members' home institutions and within the MIPL at JPL.

### 2.1 Key Task Elements

The key elements of the task are:

- 1) The establishment and operation of a scientific image processing system with elements at fourteen U.S. sites utilized by SSI team members, and the communications between these sites, the two non-U.S. sites utilized by SSI team members and the MIPL Science Processor at JPL.
- 2) The development of HIIPS elements that have the power and flexibility to meet the requirements specified in MOS-GLL-4-232. This system shall be interactive and user-friendly with an efficient command structure and syntax to support users of varied experience levels. The corresponding processing requirements for the MIPL Science Processor are defined in the MIPL Requirements Document (D-205). These requirements and the requirements for a typical HIIPS system are summarized in Figures 2-1 and 2-2 respectively.

- 3) HIIPS hardware and software that will allow rapid development and exchange of applications software, processing specifications, and other information relating to missions operations among HIIPS sites and between MIPL and HIIPS sites by means of a standard user-interface syntax and a standard application program interface.
- 4) Strict cost control.

## 2.2 Schedule

The task schedule is shown in Figure 2-3 and includes, for reference, certain significant MIPL and GLL project schedule items.

## 3 TECHNICAL PLAN

The technical plan consists of three parts: Implementation, Operations and Maintenance, and Training . The key elements of each of these parts are outlined below.

### 3.1 Implementation Elements

#### 3.1.1 General

HIIPS implementation will consist of three phases: cruise, pre-encounter and orbital operations (see Figure 2-3).

#### *Cruise phase:*

Time:	Launch until JOI minus 2 years (November, 1989 - October, 1993).
Procurements:	Only minor upgrades and continuing maintenance.
Tasks:	Analysis of in-flight calibration, analysis of cruise encounter data. Revise cruise science software as appropriate for analysis of images. Soon after EM2 encounter, switch to development of software for orbital operations.



*Pre-encounter phase:*

Time: JOI minus 2 years until JOI (November, 1993 - October, 1995).

Procurements: All sites to have newly designed HIIPS installed. These HIIPS will take advantage of new technology developments of the 1995 time-frame. The procurement and installation will be completed by no later than JOI minus 1 year.

Tasks: Install state of the art HIIPS.

*Orbital operations phase:*

Time: JOI until EOM (November 1995 - December 1997).

Procurements: Only minor upgrades and continuing maintenance.

Tasks: Conduct mission science activities.

*3.1.2 System Design*

Major use will be made of the system design and implementation experience of the MIPL project at JPL. Although MicroVAX II CPU's have been used for initial system procurement (Fig. 3-1), system upgrades will take advantage of the best technology available at the time. MIPL executive software (TAE), MIPL executive software (VICAR), MIPL application programs, as well as team-developed and other compatible application programs will be utilized.

The HIIPS system consists of twelve United States and two non-U.S. elements. The non U.S. elements are associated with team members C. Anger (York University of Ontario, Canada) and G. Neukum (DLR, Oberpfaffenhofen, Germany) and their implementation is the responsibility of their respective organizations. Only the development of a communication interface between these and the other HIIPS elements is addressed in this plan. The HIIPS elements are listed in Table 3-1.

Studies will be conducted by the SE for design decision in the following areas:

- 1) Detailed design of HIIPS for approval by the SDPG and SSI Team.
- 2) Required site preparations for all non-JPL HIIPS.
- 3) Site-dependent differences in hardware.
- 4) Sequence of HIIPS site implementation.
- 5) Effective networking of HIIPS elements.
- 6) HIIPS user training.
- 7) Others as required.

### 3.1.3 *Facility Preparation*

The objective of this activity is to identify suitable sites for each HIIPS element and to define the requirements for site preparation. Each home institution is expected to provide adequate facilities for the hardware provided under this plan, including: lighting, electrical requirements, air conditioning, and static-free floors. Costs for providing these capabilities are included in individual team member's budgets.

### 3.1.4 *Hardware Configuration*

Each site shall include a CPU and associated peripheral equipment, including an image display processor, tape and disk drives, hard copy device, and communications hardware; a possible configuration is shown in Figure 3-1.

### 3.1.5 *Hardware Procurement*

The HIIPS hardware system procurement and implementation process, including individual site differences, will be supervised by the HIIPS SE. This will include computer purchase justifications as may be required by various home institutions and JPL, appropriate competitive bids, and single-or sole-source justifications, if necessary. The installation and upgrade of individual HIIPS will be distributed over time. The hardware procurement for the HIIPS sites will consist of acquisition activities and integration

activities. Hardware procurement for the MIPL Science Processor shall be the responsibility of the MIPL Project.

#### *3.1.5.1 Hardware Acquisition Activities*

The following steps outline the acquisition of major hardware subsystems. Items 1-4 will be under direction of the HIIPS SE, as coordinated with each site team member. Items 5-7 will be the responsibility of the site team member.

- 1) In cooperation with JPL procurement officers, specify requirements and negotiate procurement, delivery, and installation schedules and enter into contracts with vendors.
- 2) Monitor vendors' progress in producing and delivering equipment according to schedule.
- 3) Maintain liaison with procurement personnel and vendor technical/ sales representative(s).
- 4) Maintain schedule of hardware acquisition to ensure timely implementation.
- 5) Accept delivery of hardware and schedule vendor participation in unpacking, inspecting and inventorying all parts, including cables, documentation, interfaces, and test apparatus for validation of bill-of-lading.
- 6) Monitor and provide reasonable support for vendor's technical representative in the mechanical, electrical, and functional checkout of equipment.
- 7) Formally accept each hardware subsystem after sufficient demonstration of unit operation.

#### *3.1.5.2 Hardware Integration Activities*

As subsystems are delivered, checked, and accepted, they will be interfaced with the overview of the HIIPS SE, coordinated with the site team member. Verification of interface integrity and subsystem compatibility will be achieved by the site team member or his representative, coordinated through the HIIPS SE, as follows:

- 1) Maintain liaison with technical representatives where multiple vendors are involved, with emphasis on hardware interface requirements.
- 2) Provide reasonable technical support for vendors where necessary to effect the installation of a hardware unit.
- 3) Observe the execution of off-line and on-line equipment diagnostic tests.
- 4) Resolve any interfacing difficulties through formal and/or informal vendor conferences.
- 5) Establish and test communications links between the HIIPS sites and the MIPL Science Processor.

#### 3.1.6 *HIIPS Software Development*

The VICAR applications executive software will be used throughout the system in either a VMS or UNIX operating system environment. VICAR's purpose is to provide a common user interface when team members are working at JPL or any of the HIIPS, I/O interface to image data, and for networking of data between same. MIPL will be responsible for this system which includes an enhanced VMS version of TAE and an integrated set of applications software. Individual team members will be held solely responsible for software failures resulting from the use of software incompatible with VICAR.

Applications software will be obtained from:

- 1) MIPL (including converted IPL applications software).
- 2) Science software as developed by team members.
- 3) Software ported from non-Galileo sources, such as Space Telescope Science Institute, and US Geological Survey.

#### 3.1.7 *System Integration*

System integration involves the coupling of site CPU's, peripherals, operating system software, executive software, applications software, and operational procedures. The HIIPS SE, in coordination with the site team member, shall be

responsible for all aspects of HIIPS system integration through the following:

- 1) Verify the physical placement of all computer hardware units.
- 2) Verify adequacy of power, communications, environmental controls, etc.
- 3) Verify the planned interfaces (hardware and software) between all systems, their locations, and their access.
- 4) Tune each system for optimum operation including local site job mix (CPU- and I/O-bound tasks), sharing of software packages, and efficient I/O.
- 5) Monitor installation of hardware, operating system software, and application software packages. Observe demonstrations of these in operation, one system at a time, prior to allowing the system executive to communicate with other systems
- 6) Provide media backup, supplied by MIPL, in the form of a master copy of all basic system software.
- 7) Monitor hardware maintenance contracts to assure that an acceptable level of hardware performance is maintained.
- 8) Establish and maintain communications between the HIIPS sites and the MIPL Science Processor.

#### 3.1.8 System Test

The system test activity will:

- 1) Validate the integrated system.
- 2) Quantify the functional capabilities.
- 3) Assess system performance characteristics.

Test procedures will serve to periodically verify system performance and to detect areas where specific subsystem diagnostics are required for troubleshooting. The system test applies only to standard HIIPS hardware and software items; non-standard HIIPS peripherals shall be the responsibility of the site team member.

The system test will be directed by the HIIPS SE and includes:

- 1) Review all relevant subsystem specifications that control capabilities and performance.
- 2) Design, construct, and document a set of test programs which validate the capabilities and performance as specified in MOS-GLL-4-232.
- 3) Verify the adequacy of CPU, main memory, I/O, and mass storage to meet HIIPS requirements.
- 4) Evaluate and document all test results.
- 5) Consult with vendor and MIPL representatives regarding test evaluations and adequacy of performance.
- 6) Consult or contact users on test evaluation and adequacy of performance and provide for continued user "feedback."
- 7) Prepare a test plan for periodic verification of overall system integrity.
- 8) Support testing of individual HIIPS system elements.
- 9) Support testing of communications between HIIPS sites and the MIPL Science Processor.

### *3.2 Operations and Maintenance Elements*

Operations support provided by the MIPL Science Processor is documented in the MIPL Operations and Maintenance Plan and associated memoranda of agreements. The HIIPS plan includes the following elements:

- 1) Daily operational procedures.
- 2) Periodic backups of the software.
- 3) Restoration procedures in case of system crashes.
- 4) Failure reporting procedures, both locally and to the HIIPS SE.
- 5) Access by non-project planetary users and other users, including user-priorities.

- 6) Maintenance of HIIPS, including both hardware PM's and software updates.

### 3.3 *Scientific Data Processing Training Elements*

The training phase is a continuing effort, since new VICAR procedures and programs are constantly being developed by the GLL SSI Team and by the MIPL science processors. It includes the following elements to familiarize the GLL SSI science team and associates with the HIIPS and MIPL science processors:

- 1) Use of hardware on both HIIPS and MIPL science processors.
- 2) Standard log in and log out procedures for both HIIPS and MIPL processors.
- 3) Understanding the various user modes of TAE (interactive: command, tutor, menu; batch).
- 4) Use of image processing software in the VICAR environment.
- 5) Use of data base management software for accessing the image catalog.
- 6) Use of communications software for exchanging information between both MIPL/HIIPS and HIIPS/HIIPS.

## 4 MANAGEMENT

System design, implementation, and testing shall be managed by the HIIPS SE who will report to the Scientific Data Processing Group of the SSI Science Team. Cost control for the task shall be maintained by the Galileo Science Manager. Operation and maintenance of each HIIPS facility shall be the responsibility of the team member or members directly served thereby.

### 4.1 *Organization*

The organizational relationships necessary to accomplish this task are shown in Figure 4-1.

The Galileo Science Manager's responsibilities include:

- 1) Providing overall direction of this task.
- 2) Approving overall goals and directions of this task.
- 3) Establishing project schedule guidelines.
- 4) Approving task plans and budgets.
- 5) The Galileo Solid State Imager Science Team's responsibilities include:
  - 6) Setting overall goals and requirements, and approving the HIIPS Implementation Plan and other plans.
  - 7) Establishing science schedule milestones.
  - 8) Resolving incompatibilities between requirements and resources based on science needs and available resources.
  - 9) Coordinating interactions with activities outside the task (such as real-time and systematic processing).
  - 10) Developing HIIPS unique applications software and identifying required software from other sources such as the Space Telescope Science Institute.
  - 11) Providing a single interface between all HIIPS activities and the MIPL implementation and operations activities (as depicted in Figure 4-1).

The Science Data Processing Group (SDPG) reports to the GLL SSI Science Team and is responsible for planning, organizing, staffing, directing and controlling the activities such that task objectives are achieved and requirements are met on schedule and within budget. Specific responsibilities include:

- 1) Developing detailed plans in response to the objectives and requirements specified by the GLL SSI Science Team.
- 2) Identifying incompatibilities between requirements and available funding for resolution by the GLL SSI Science Team.



- 3) Maintaining Level 3 schedules in accord with guidelines specified by the GLL Science Manager.
- 4) Monitoring task budgets and schedules (level 3), and assuring compliance.
- 5) Organizing, scheduling, and arranging for the presentation of reviews and reporting mechanisms dictated by this Task Plan.
- 6) Ensuring that provisions of this Task Plan are carried out.
- 7) Ensuring that the approach dictated by the Implementation Plan is carried out.
- 8) Carrying out responsibilities defined later in this document for reviews and quality assurance.

The HIIPS SE reports to the SDPG and is responsible for the HIIPS system hardware and software design and implementation. Specific responsibilities include:

- 1) Ensuring traceability of the design to the requirements.
- 2) Establishing and maintaining a system philosophy or system model to facilitate HIIPS reliability, low cost operations, portability of software, and interchangeability of peripheral hardware.
- 3) Allocating functions to hardware and software.
- 4) Conducting trade-off studies.
- 5) Establishing and maintaining a loading analysis and margin maintenance activity for elements of the system, such as CPU, main memory, and disc.
- 6) Maintaining Level 4 schedules.
- 7) Developing and publishing plans for HIIPS implementation, training, operations, and maintenance.
- 8) Carrying out responsibilities defined later in this document regarding reviews and quality assurance.

- 9) Supervising hardware procurement and implementation defined in the HIIPS Implementation Plan, in the HIIPS Hardware Specification, and in the HIIPS ADPE Acquisition Plan.
- 10) Maintaining level 5 hardware schedules.
- 11) Planning, documenting, and carrying out HIIPS system integration (hardware, software, and procedures), and independent testing of HIIPS capabilities.
- 12) Coordinating the SSI Team-level exchange of HIIPS and non GLL applications software.
- 13) Supervising plans for site preparation and obtaining agreements from each participating institution to assure appropriate site preparations to support the schedule for implementation.

The Galileo Image Processing System Engineer's responsibilities include:

- 1) Providing support to the HIIPS SE in areas of documentation, studies, and reviews.
- 2) Advising the GLL Science Manager on issues relative to schedule, cost and risk.
- 3) Providing support to the SDPG on documentation.

The MIPL/HIIPS Liaison Engineer's responsibilities for implementation include:

- 1) Providing support to the HIIPS SE regarding MIPL hardware and software.
- 2) Supporting definition of the applications software.
- 3) Supporting studies and implementation of HIIPS and MIPL science processor interface and communications facilities.
- 4) Coordination of SSI Team review and critique of MIPL applications software.

The MIPL/HIIPS Liaison Engineer's responsibilities for operations include:

- 1) Providing support to the HIIPS SE regarding MIPL hardware and its operation.
- 2) Supporting definition of the Science Processor operations and scheduling.
- 3) Supporting operation of HIIPS/MIPL communications interface.
- 4) Coordination of SSI Team review and critique of MIPL operations and procedures.

The HIIPS Site Managers' responsibilities include:

- 1) Preparing plans for automatic data processing equipment or other plans required by their home institutions.
- 2) Coordinating site planning consistent with hardware and user requirements.
- 3) Negotiating site preparation by benefiting home institution.
- 4) Supporting hardware delivery, integration and test.
- 5) Supporting software installation and test.
- 6) Supervising operations and maintenance of site facilities.

#### 4.2 Schedules

The Level 3 schedule shown as Figure 2-3 includes overall task milestones. Its maintenance is the responsibility of the SDPG.

Level 4 schedules shall be produced and maintained by the HIIPS SE for studies, reviews, site preparation, hardware, software integration, and testing. These schedules will show sufficient detail to identify monthly activities.

Level 5 schedules shall be produced and maintained by the HIIPS SE as deemed necessary for areas needing more frequent monitoring.

#### 4.3 *Reporting*

The HIIPS SE shall report task status and plans at regular meetings of the Science Processing Data Group.

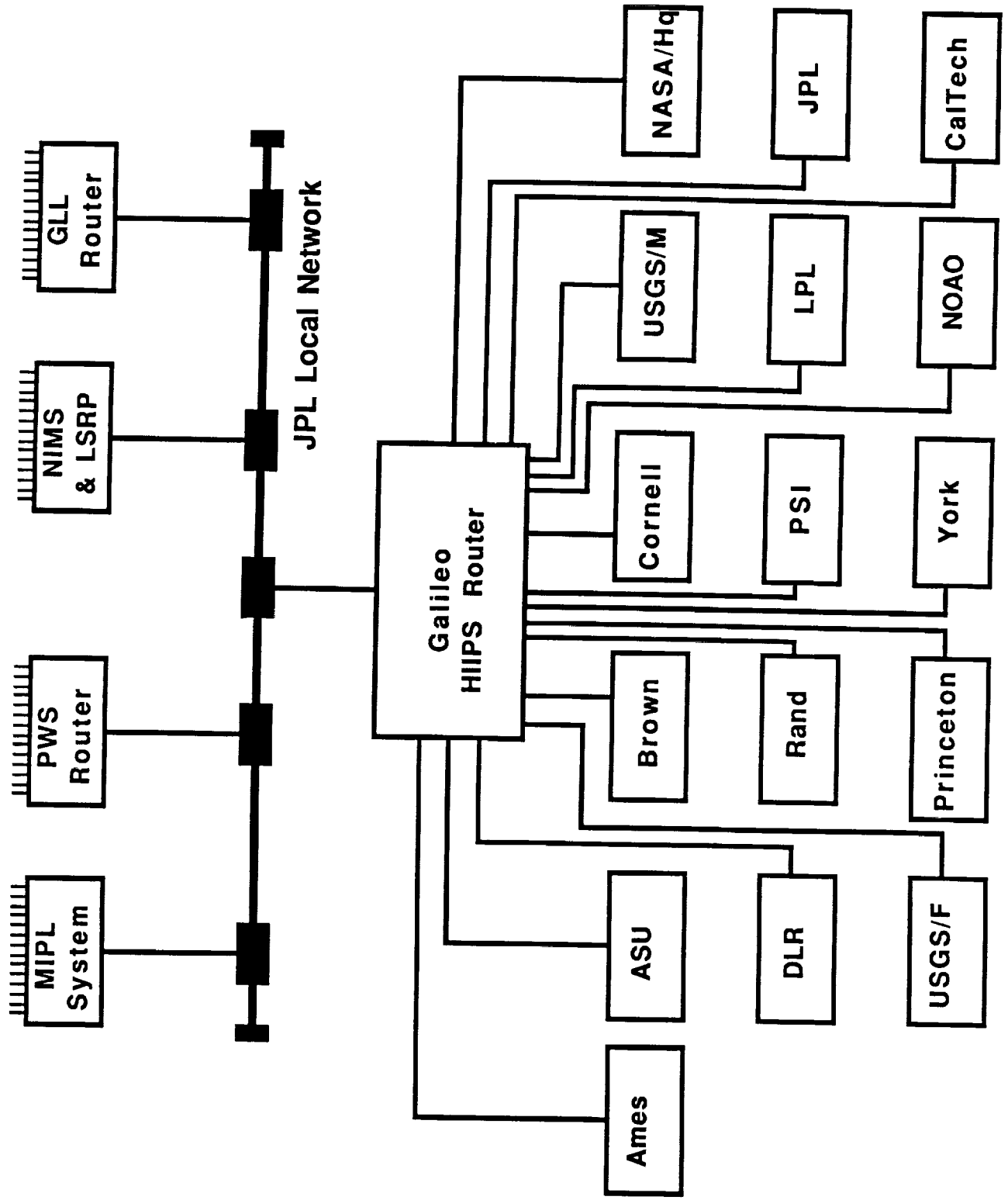
#### 4.4 *Quality Assurance*

Quality assurance for this task shall be provided by documentation and regular reviews.

Documentation shall be produced detailing the results of all study and design activities. This documentation shall provide the rationale upon which decisions are based as well as the results. In addition to study reports, the HIIPS SE shall produce an Implementation Plan, an Operation and Maintenance Plan, and a Training Plan.

Reviews shall be scheduled as appropriate and held jointly by the GLL Science Manager and the GLL SSI Science Team. The HIIPS SE shall organize and conduct these reviews.

Figure 1-1. Diagram of Galileo Image Processing System During Planetary Operations



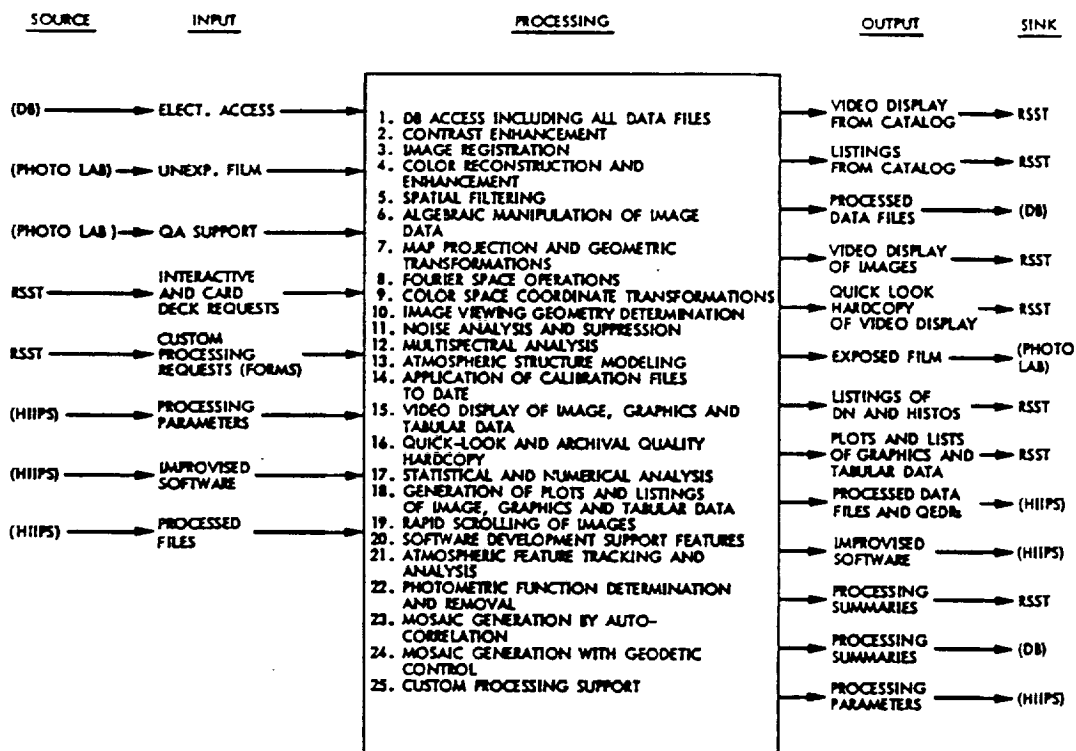


Figure 2-1. SSI Science Interactive Processing Element Functions  
(Sources and Sinks in Parentheses are Internal to the IPS)

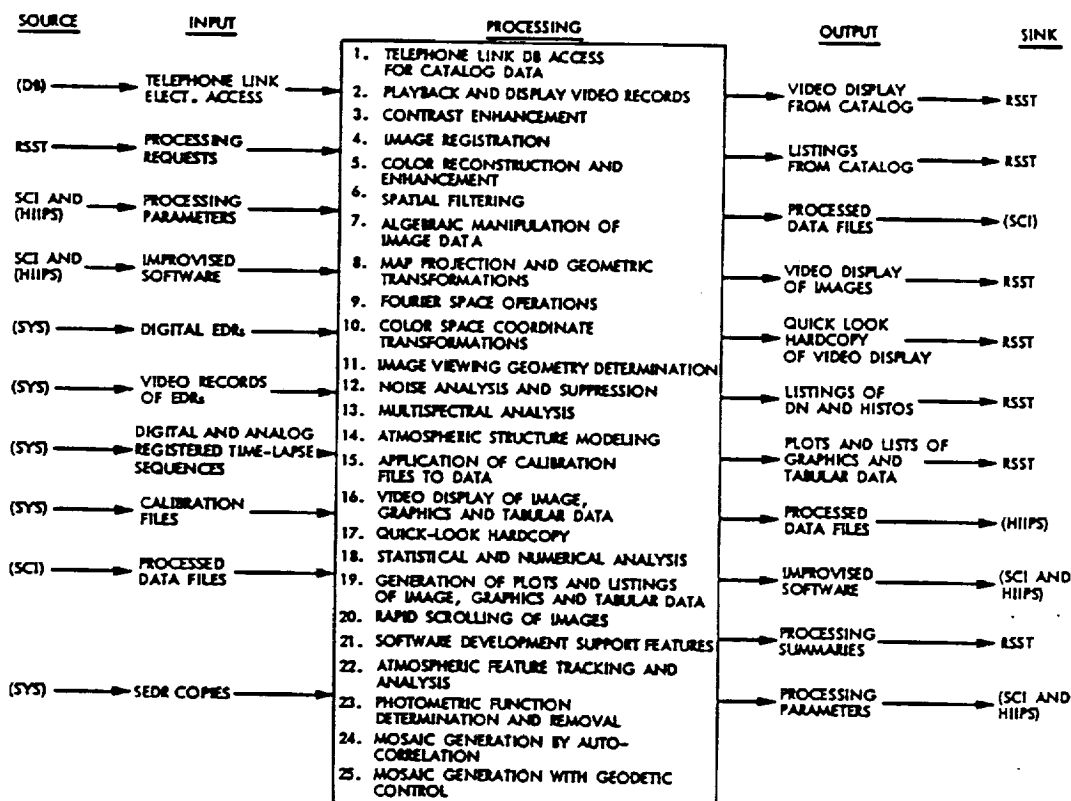
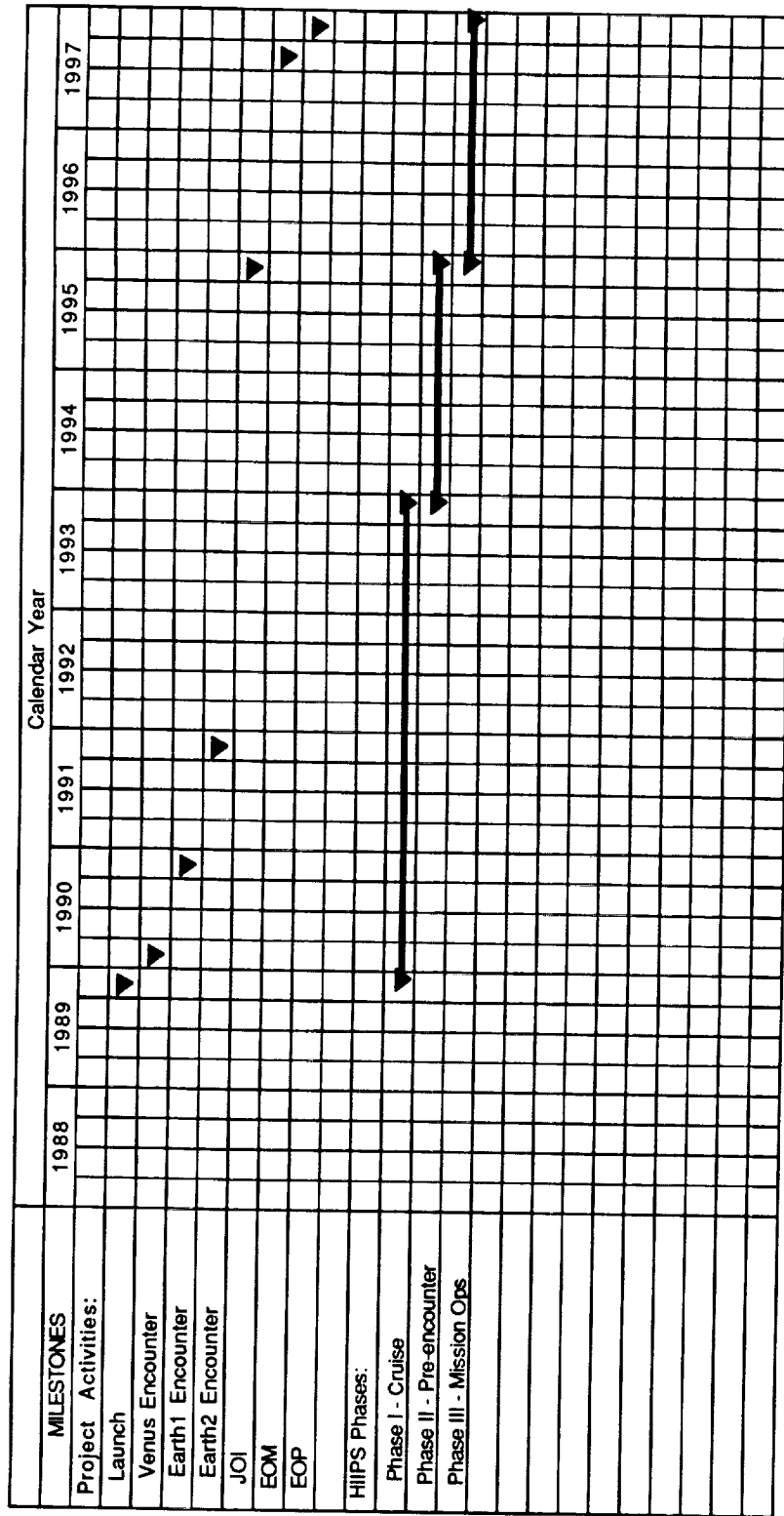
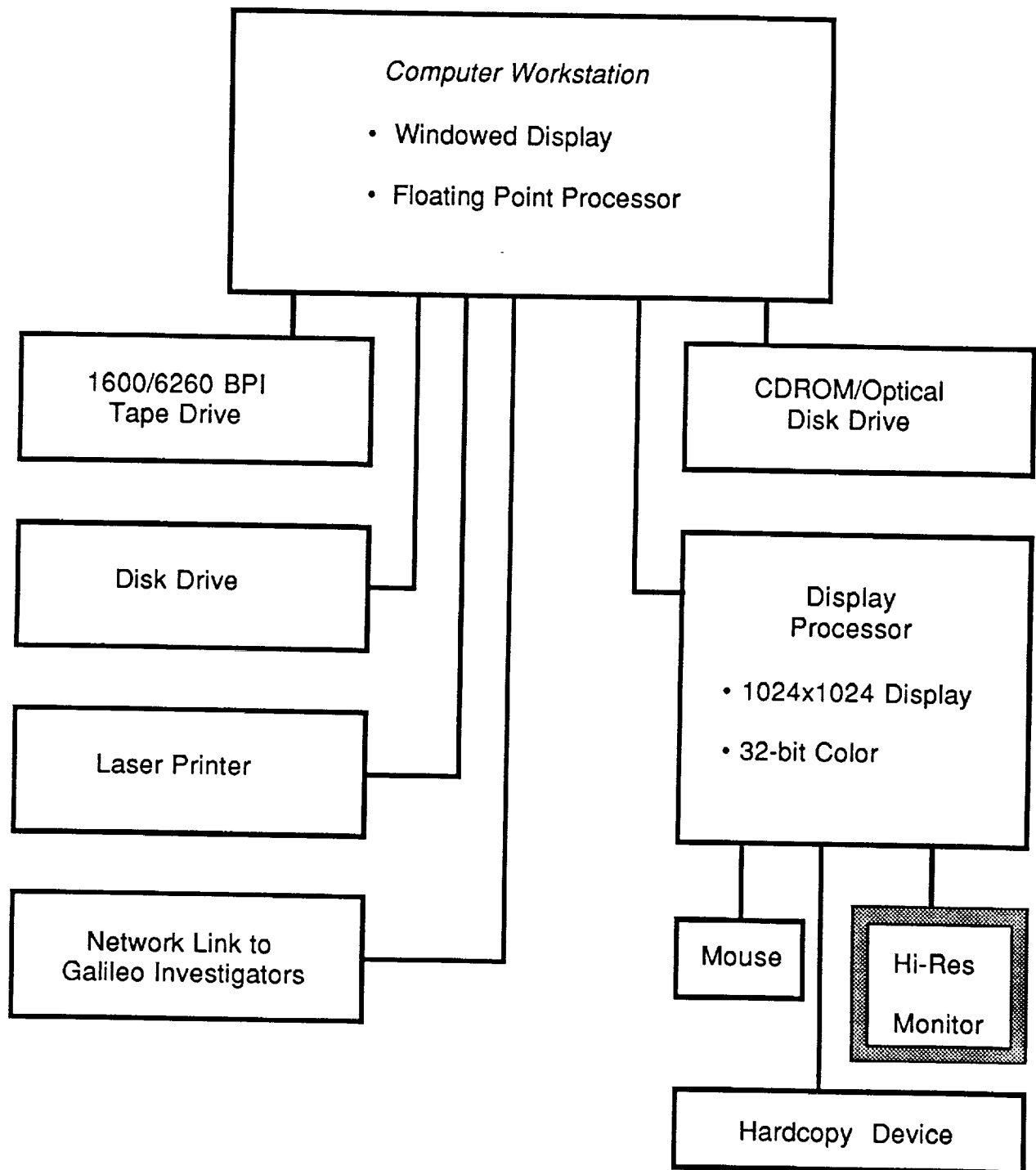


Figure 2-2. Home Institution Image Processing Elements Functions (Sources and Sinks in Parentheses are Internal to the IPS)

Figure 2-3. HIPS 1990 Timeline



### Figure 3-1. HIIPS Hardware Diagram





**Table 3-1. Galileo HIIPS Sites**

<b>Institution</b>	<b>Location</b>	<b>Team Members, Associated IDss (*)</b>
Ames Research Center	Moffet Field, CA	J. Pollack* D. Morrison*
Arizona State University	Tempe, AZ	R. Greeley
Brown University	Providence, RI	J. Head
California Institute of Technology	Pasadena, CA	A. Ingersoll*
Cornell University	Ithaca, NY	J. Veverka P. Gierasch*
DLR	Oberpfaffenhofen, West Germany	G. Neukum
Jet Propulsion Laboratory	Pasadena, CA	K. Klaasen
Lunar and Planetary Laboratory	Tucson, AZ	R. Greenberg
National Optical Astronomy Observatories	Tucson, AZ	M. Belton
Planetary Science	Tucson, AZ	C. Chapman
NASA HQ	Washington, DC	C. Pilcher
Rand Corporation	Santa Monica, CA	M. Davies
US Geological Society	Menlo Park, CA	M. Carr
US Geological Society	Flagstaff, AZ	H. Masursky*
York University	Ontario, Canada	C. Anger*
University of Hawaii	Honolulu, HI	F. Fanale*

**Figure 4-1. HIIPS Scientific Data Processing Organization Chart**

